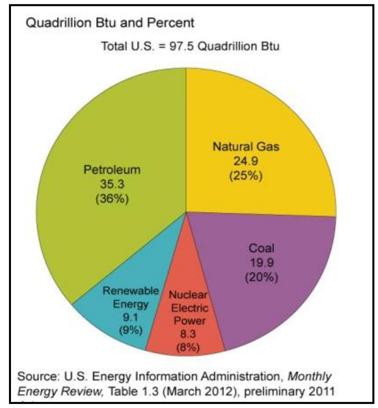
Adaptive Control of Subsurface Fractures and Fluid Flow

A DOE National Laboratory mission to revolutionize energy production and subsurface storage



Distribution of U. S. energy sources

Problem Description:

The deep subsurface supplies >80% of U.S. primary energy and provides a vast potential storage resource for CO_2, nuclear waste, and energy. Despite decades of exploitation, subsurface energy resources are underutilized; only ~10 to 40% of the oil and gas is recovered from shale and conventional reservoirs, respectively. Additionally, environmental risks are often not well integrated into subsurface energy and storage strategies, thereby threatening public confidence in the energy sector. Game-changing advances are needed to revolutionize utilization of the subsurface for energy production and storage while also protecting the environment.

Adaptive control of subsurface fractures and fluid flow is a grand challenge that has the potential to transform subsurface energy strategies. Control is defined as the ability to adaptively manipulate fracture length, aperture, height, branching patterns, and associated fluid flow. This grand challenge is critical for optimizing production of unconventional hydrocarbons as well as geothermal energy. In nuclear waste disposal, minimization of fracturing in the near-field damage zone surrounding emplacement locations is critical for safe storage. For CO_2 sequestration, energy storage (e.g., natural gas or compressed air), or disposal of liquid wastes, engineered and existing fractures can be used to improve injectivity; fractures in the confining layer can be plugged to prevent fluid leakage, and induced seismic hazard can be reduced.

Major advances are needed to enable “fractures-by-design”. The main challenges include variable lithology, structure, stresses, fracture initiation and growth processes, geochemical reactions (both in the fractures and at mineral grain boundaries in the rock matrix), and multi-phase flow, all in the deep subsurface accessible only by wells. To realize the full potential of the subsurface resources for energy security, game-changing improvements are needed in characterization, monitoring, prediction and ultimately control of fracture and flow processes over scales ranging from nanometers to kilometers.

Envisioned End State:

Developing the requisite scientific understanding and engineering solutions to enable the control of new and existing fractures and related fluid flow will be transformational, enabling over the next decade:

- Doubling of the recovery efficiency of oil and gas from low-permeability reservoirs;
- A ten-fold increase of U. S. electricity production from geothermal reservoirs;
- Large-scale CO_2 sequestration to meet targets described in the President’s Climate Action Plan;
- Technical basis for safe disposal of nuclear (and other) wastes;
- Protection of the surface environment and resources such as freshwater aquifers; and
- Continued U. S. leadership in the development of cutting-edge subsurface energy technologies.

Expected Benefits:

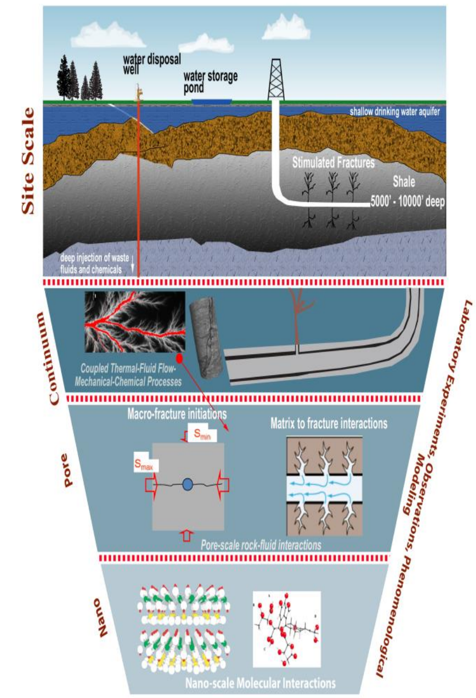
The energy and environmental benefits of the proposed plan apply to hydrocarbon and geothermal heat recovery as well as energy and waste storage. They include:

- Dramatically improved per-well recovery, resulting in reduced number of oil and gas wells and:
    - Reduced fugitive methane emissions;
    - Reduced surface environmental footprint;
    - Reduced water use and disposal requirements;
    - Reduced capital and operational expenses;
- Reduced risk of seismic activity from fracture stimulation and fluid injection;
- Large-scale energy/waste storage including compressed air energy storage and CO_2 storage;

- Increased scientific and public confidence in subsurface energy technologies;
- Demonstrated success utilizing collective National Lab expertise and facilities to solve a complex national challenge.

Scope of work:

Characterization, prediction, and ultimately control of subsurface fracture and flow will require coupling of experimental and high-performance computational approaches: strengths of the national laboratory system. To locate, image, and create fractures-by-design, research and development is needed across a wide range of technical areas and scales (length and time), using high-performance computational and user facilities, and teaming with industry and academia from the beginning. Fundamental research is needed in the areas of fracture mechanics, fluid flow, reactive geochemistry, water-rock reactions, and multi-scale characterization. High-resolution imaging, novel sensing technologies, field characterization, and control logic will be integrated with studies of the dynamics of fracture initiation/dislocation and growth. Experiments will be coupled with multi-scale, multi-physics mechanistic and phenomenological models to develop next-generation simulators of fracture and fluid flow. Scale up of monitoring and adaptive control methods to intermediate (1-10 m) and field (10-10^3 m) scales will be required to develop operational capabilities. New technologies will be developed to enhance subsurface reservoir stimulation, improve subsurface access, ensure wellbore integrity and quantify environmental risks. Field-scale experiments to demonstrate these new technologies and developed adaptive fracture and fluid-flow control approaches will be undertaken in partnership with industry.



Example scale range of processes associated with shale hydrocarbon production

Federal Role:

The mission of the Energy Department is to ensure the Nation’s security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions. Industry has made progress in understanding and characterizing fractures in the subsurface related to energy extraction, but much work remains to achieve truly game-changing advances. The Federal government has a role to play in the development of next-generation “control” technologies that will spur industry investment and implementation. The National Laboratory system has unique facilities, computational resources and expertise to provide breakthrough technological advances that, when working with industry, will benefit a broad range of energy industries focused on energy production and storage strategies, super-majors and independent producers, alike. The developments will simultaneously provide the technical basis of environmental risk to inform policy and regulatory decisions - a role that is well suited for the Federal Government. A Community Hub & Spoke Subsurface Framework will coordinate, integrate, and prioritize basic through applied research to advancing crosscutting fracture knowledge and ‘control’ approaches and demonstrating new technologies at Energy Observatories. Energy Observatories serve as field experimental platforms for testing, demonstration, and partnership with industry and regulators. Together with these partners, the Energy Department will lead the Grand Challenge effort of adaptive control of subsurface fractures and fluid flow for the benefit of the Nation’s energy and environmental future.

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